Using Prescribed Fire to Regenerate Oaks

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Abstract

Fire is widely recognized as having been a major force shaping the character of eastern hardwood forests. Exclusion of periodic surface fires from mixed hardwood stands for over 70 years has contributed to the gradual succession of shade-tolerant species into the understory and midstory of these stands. Following major disturbance to the overstory, these shade-tolerant species or pioneer shade-intolerant species are able to out-compete oak regeneration and dominate the next stand. Because of fire exclusion for many decades, regeneration of oak-dominated stands has been a major silvicultural problem. Recent research indicates that a shelterwood-burn technique, which mimics the natural disturbance regime that historically favored oaks, can be used on productive upland sites to enhance the competitive position of oaks in the advance regeneration pool. This paper presents silvicultural guidelines for applying the technique and discusses several options to meet the management objectives of different landowners.

Introduction

Regenerating oaks on good quality sites has been a difficult problem throughout the eastern United States for many decades. Oak regeneration failures have generally been attributed to either poor initial establishment of oak seedlings or the slow juvenile growth of oak advance regeneration when it is present (Abrams 1992, Lorimer 1993, Loftis and McGee 1993). In the dense shade of mature mixed-hardwood stands, oak seedlings and seedling sprouts do not develop into competitive stems. Overstory removal by either partial or complete cuttings releases well-established shade tolerant regeneration and facilitates establishment of fast-growing shade intolerant seedlings. Subsequent stand development is to a mixed mesophytic forest with oak as a minor component or altogether absent (McGee 1979; Abrams 1992; Lorimer et al. 1994). This successional trend is a relatively recent phenomena, developing in the past 75 years, and is tied to the exclusion of fire from eastern hardwood forests (Little 1974; Van Lear and Johnson 1983; Lorimer 1993).

Fire research in hardwoods has lagged far behind that in pines, although several studies suggested that oaks were ecologically adapted to frequent burning (Swan 1970, Niering et al. 1970, Thor and Nichols 1974, Waldrop et al. 1987, Augspurger et al. 1987). All of these studies noted that oaks resisted root kill by fire to a greater extent than their competitors. Numerous authors, based on literature reviews, accounts of early explorers and settlers, observed vegetative patterns and responses, and other evidence, have concluded that fire played an important role in the development and maintenance of oak forests in the eastern United States (Little 1974; Van Lear and Johnson 1983; Crow 1988; Van Lear and Waldrop 1989; Williams 1989; Abrams 1992).

In this paper, we will discuss the use of fire as a silvicultural tool to regenerate oaks. Particular emphasis is placed on a new regeneration method that utilizes partial harvesting followed by prescribed fire.

Interactions Between Fire and Oaks

With the arrival of Indians in the eastern United States as early as 12,000 years ago, fire became a more frequent disturbance that shaped forest composition and structure (Pyne 1982; Williams 1989). Indians used fire for many reasons, including hunting, facilitating travel, stimulating berry production, clearing land for agricultural crops, and as a defense against enemies. The frequent, widespread use of fire by Indians and the European settlers that followed them created an environment favorable for the establishment and maintenance of oaks. In the early 1900s, fire-suppression efforts of the U.S. Forest Service and state forestry commissions began to be successful in reducing the frequency, extent, and influence of this powerful environmental force. The forest changed dramatically as fire was largely removed from the Eastern forest ecosystem. Shade-tolerant and fire-intolerant species began to dominate forest understories, overstory densities increased, and fire-sensitive species moved upslope from moist coves to xeric slopes.

Frequent burning creates environments that favor oaks on better-quality sites. Surface fires remove much of the mid- and understory strata in mature mixed hardwood stands, reducing shading. Spring fires are especially effective (Barnes and Van Lear 1998). Fire reduces the thickness of the forest floor, preparing a favorable seedbed for caching of acorns by squirrels and jays by (Darley-Hill and Johnson 1981, Galford et al. 1989). Fire reduces surface soil moisture which discourages establishment of mesophytic species (Barnes and Van Lear 1998) and may control insect predators of acorns and new seedlings (Galford et al. 1989).

The presence of oaks encourage surface fires because of the nature of their litter. An oak stand adds about 4.5 $Mg ha^{-1} yr^{-1}$ of leaf litter to the forest floor (Loomis 1975). This litter remains curly, creating a porous fuelbed for surface fires. Unlike leaf litter of mesophytic species which forms a flat mat upon compaction and decays rapidly, oak leaf litter undergoes little decay during the winter. In regions where snowpacks are heavy, oak litter recurls after snowmelt, once

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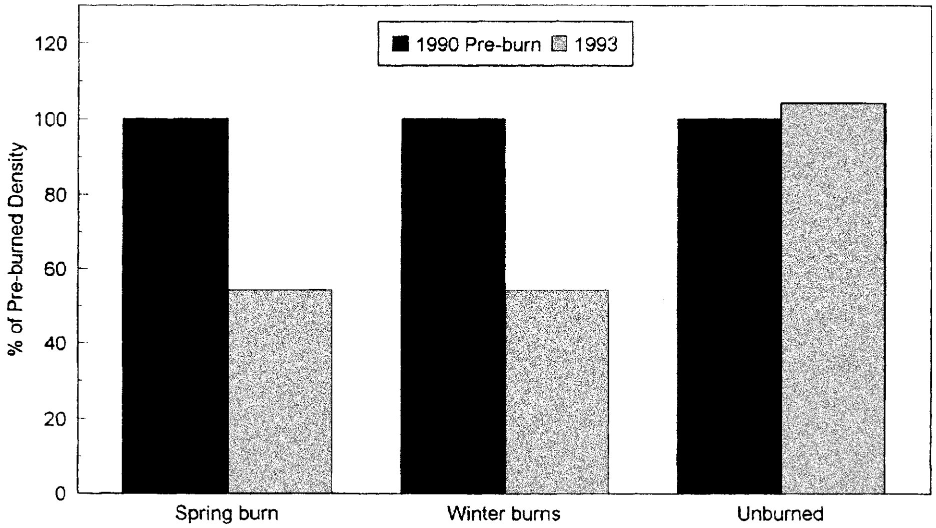

Figure 1.—Reduction of midstory/ understory densities following three winter burns and one spring burn in mixed hardwood stands in the South Carolina Piedmont.

again creating a porous fuelbed capable of carrying a surface fire during the spring fire season (Lorimer 1989).

Because of the complexity of forest ecosystems, effects of fire in hardwood stands vary. Fires in stands of mixed composition have occasionally created oak-dominated stands (Roth and Hepting 1943; Carvell and Maxey 1969; Ward and Stephens 1989), probably because intense fires controlled competition and stimulated rapid growth of oak reproduction (Johnson et al. 1989; Lorimer 1989). In other cases, species composition in young stands has been altered very little by fire (Johnson 1974; McGee 1979; Waldrop et al. 1985; Augspurger et al. 1987).

Effects of fire vary because of differences in season of burning and fire intensity. Season of burning affects physiological condition of the plant and the ability of species to resprout. Hardwoods have the greatest ability to sprout when carbohydrate storage in their roots is high, i.e., in the dormant season. In the growing season, root reserves are lower and sprouting vigor is less. Fire intensity is critical because certain species, such as the oaks, can survive higher intensity fires than their competitors (Brose and Van Lear 1998) because their sprouts originate deeper in the soil than those of their competitors (Hane 1999).

Using Fire to Encourage Oak Regeneration

Understory Burning

Fire exclusion for most of the past century has altered stand structure and composition of eastern hardwood stands. Shade-tolerant and fire-intolerant species have gradually encroached into the understory of oak-dominated stands. Now, in the absence of periodic fire, there is no growing space for oak reproduction, which may or may not be present in the advanced regeneration pool. Van Lear and Watt (1993) developed a theoretical silvicultural prescription to encourage oak regeneration by burning the understory of mature mixed hardwood stands near the end of the rotation. Barnes and Van Lear (1998) tested this hypothesis in the Piedmont of South Carolina and found that one burn early in the growing season when leaves were expanding was as effective as three winter fires in reducing density of understory and midstory stems (fig. 1). The number of oak rootstocks in the regeneration layer was increased by burning, root/shoot ratios of oaks were enhanced, and competitive woody species decreased. There was little visible damage to boles of overstory oaks from the fires, especially in the larger size classes.

Although oak regeneration was increased by understory burning, it remained small and generally ephemeral. It appeared that burning would have to be continued for a relatively long period, i.e., perhaps 10 years or so, before sufficient oaks of competitive size would be present in the advance regeneration. Such an approach is handicapped by the expense and risks of multiple prescribed fires, making it a rather unattractive option for landowners and managers. Nevertheless, if no advance regeneration exists in a stand, periodic understory burning may provide a means to establish oak seedlings and seedling sprouts, which could then be encouraged to begin vigorous growth by the following technique.

Shelterwood Cutting Followed by Prescribed Fire

The Shelterwood-Burn Method

Oak-dominated stands on better quality sites in the southern Piedmont and mountains often have abundant but small and non-competitive oak reproduction in the regeneration layer. When such stands are harvested by either clearcutting or the shelterwood method, oak reproduction cannot compete with rapidly growing shade-intolerant species and/or well-established shade-tolerant species (Loftis 1983, Abrams 1992, Schuler and Miller 1995).

A shelterwood-burn method (fig. 2) has recently been developed in the Piedmont of the southeastern United States to enhance the competitive position of oak regeneration in such stands (Keyser et al. 1996; Brose and Van Lear 1998; Brose et al. 1999a). This method is based on the silvics and fire ecology of oak and yellow-poplar regeneration and involves an initial shelterwood harvest which removes roughly half of the overstory basal area. All yellow-poplars are removed in this first cut of the two-cut shelterwood method, leaving the best dominant and codominant oaks. Logging slash must be kept away from bases of residual oaks by directional felling. This partial harvest is followed by a 3- to 5-year waiting period, after which a relatively hot growing-season prescribed fire is run through the advance regeneration.

Oak reproduction must be relatively vigorous and free-to-grow to be competitive. We defined such oaks as straight stems at least 1.3 m tall with no major competitors within 3 m (Nix 1989). Oaks resist root kill by fire better than yellow-poplar and other competitors, especially as fire intensity increases (fig. 3) (Brose and Van Lear 1998). Density of free-to-grow oaks exceeded 800 stems/ha and yellow-poplar density was greatly reduced (up to 90%) in areas burned in the spring with high intensity flames. In contrast, winter burns provided little control of yellow-poplar and, even with a high intensity fire, oaks density did not reach 300 stems/ha. Summer fire resulted in substantial numbers of free-to-grow oaks in all fire intensity levels, but especially in the two medium intensity levels. High intensity summer fires killed many of the smaller oak seedlings while low intensity summer fires failed to control competition.

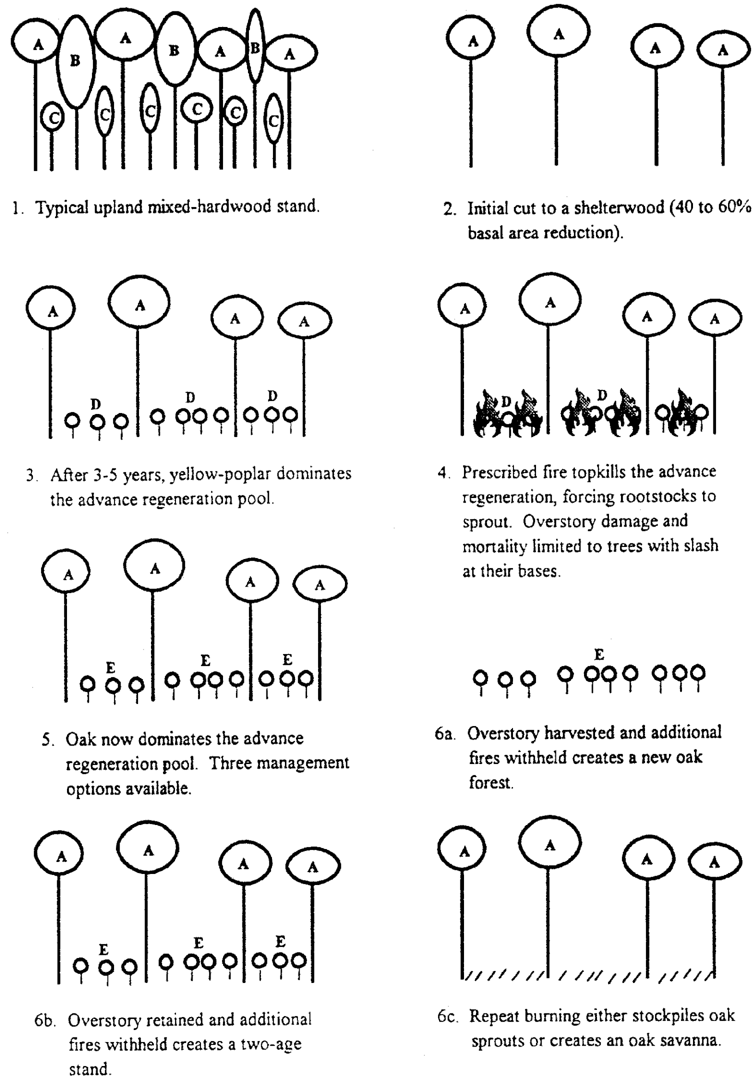

Figure 2.—Schematic diagram of the shelterwood-burn technique. A = high quality oaks; B = hickories, poor quality oaks, and yellow-poplars; C = American beech, flowering dogwood, and red maple; D = mixed hardwood regeneration dominated by yellow-poplar; and E = mixed hardwood regeneration dominated by oaks.

Oak reproduction will not be uniform over the entire burned area. If free-to-grow oaks exceed 370/ha and 60% or more of the stocking plots have at least one free-to-grow oak, the stand can be considered regenerated with the likelihood that oaks will be a dominant component of the next stand. One burn may not be enough if oak dominance is desired in the new stand. Decades of fire exclusion have allowed oak competitors to become firmly established. If more oaks are desired, additional fires may be prescribed as dictated by leaf litter accumulation. We believe that oak dominance of the advance regeneration will continually increase with repetitive spring burning at about 2-year intervals.

We believe that a shelterwood cut, rather than a clearcut, is the essential first step in this technique. The shelterwood continues to produce oak litter which creates the continuous fine fuel bed necessary to carry the subsequent fire. If a clearcut had been used, foliage from yellow-poplar, a poor medium for carrying surface fires, would dominate the forest floor. In addition, shading from the shelterwood prevents yellow-poplar regeneration from growing so large during the interval before burning that it could not be killed by fire (Hane 1999).

In the 3 to 5- year period following the initial cut, logging slash settles and loses it’s foliage, minimizing the risk of bole damage to residual trees caused by flareups in heavy fuels (Brose and Van Lear 1998; Brose et al. 1999a). Although yellow-poplar was removed in the initial shelterwood cut, its seed remains viable in the duff for up to 10 years (McCarthy 1933). Most of this stored seed germinates during the waiting period and those seedlings are killed in the subsequent fire. The waiting period also allows residual overstory trees to recover from the shock of the initial cut before they will be stressed again by burning.

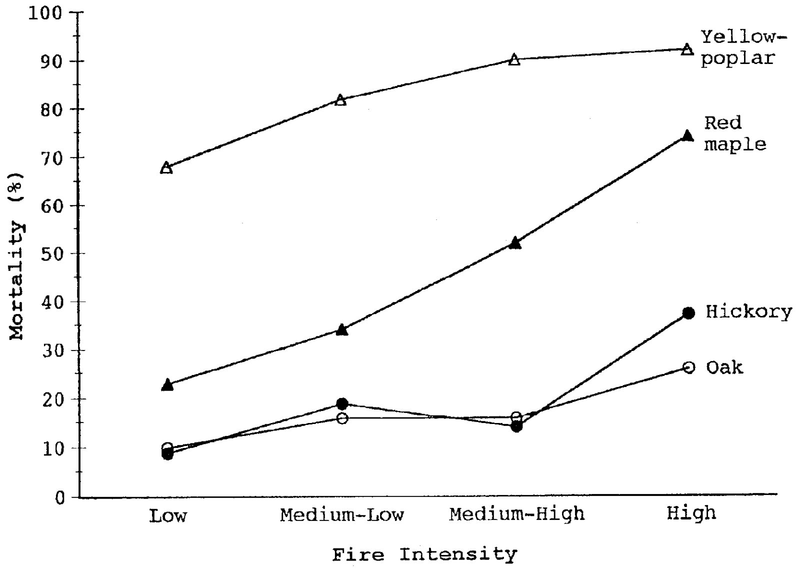

Figure 3.—Mortality (%) of hickory, oak, red maple, and yellow-poplar advance regeneration as fire intensity increases within spring prescribed burns conducted in shelterwood stands.

Advantages of the Shelterwood-burn Technique

The shelterwood-burn method is attractive to landowners because the initial cut of the shelterwood method produces immediate income. A small portion of the profit is then used to pay for the prescribed burn. Careful planning, e.g., consider using skid trails for fire breaks, before timber harvest can reduce later prescribed fire costs. Removal of the shelterwood after burning is at least as profitable as the initial cut because the best oaks were retained and some probably increased in value during the intervening years before final harvest.

If the landowner's goal is to manage for wildlife, the shelterwood-burn method can be used to sustain hard mast production while providing a source of palatable browse during the regeneration period. Landowners can maintain indefinitely the classic structure of the shelterwood while stockpiling oak regeneration with periodic burns (Brose et al. 1999b). Many upland game and non-game species utilize the mast, browse, and cover in a regenerating shelterwood (Brose et al. 1999b; Lanham et al. 2000). A note of caution – in areas where deer density is extremely high and early successional habitat is relatively rare, the shelterwood-burn method probably will not work because of over-browsing of oak regeneration.

The shelterwood-burn system could be used to restore fire-maintained ecosystems (Brose et al. 1999b). Frequent growing season burns after the initial shelterwood cut would gradually reduce woody regeneration (even the oaks) and create a hardwood woodland or savannah, two habitats that have become increasingly rare after decades of fire exclusion (Buckner 1983; Pyne 1982; Van Lear and Waldrop 1989; Abrams 1992).

Research suggests that the shelterwood-burn technique may be successful in other physiographic regions and on different sites. Repeated burning in oak-pine communities on xeric sites in the Cumberland Plateau reduced regeneration of red maple and other non-oak species and promoted chestnut oak regeneration (Arthur et al. 1998). On mesic sites in Wisconsin, two spring burns reduced densities of sugar maple and hophornbeam by 80%, while density of northern red oak increased (Kruger 1992). Ward and Gluck (1999), in Connecticut, observed that burning several years after a shelterwood harvest favored oaks and reduced competition from birch and shrubs. Hot fires in mountain laurel thickets in the Northeastern United States that opened canopies, i.e., a disturbance similar to a shelterwood harvest, allowed oak reproduction to grow past the dense shrub layer (Moser et al. 1996).

Conclusions

Oak forests on good quality sites have been in decline in the eastern United States for decades as more shade-tolerant species gradually succeed oaks or shade-intolerant species outgrew them after a major disturbance. Fire historically played a major role in maintaining oak-dominated forests but periodic surface fires have been excluded from these sites for over 70 years.

Practical silvicultural prescriptions using fire for oak regeneration have been lacking. Understory burning in mature mixed hardwood stands creates environmental conditions which should favor oak regeneration but developing oak reproduction does not reach sufficient size to be competitive when the overstory is removed.

A shelterwood-burn technique has recently been developed which overcomes this major disadvantage. This technique reduces the vigor of oaks' competitors, especially if growing season burns of relatively high intensity are used, and provides conditions (increased light and reduced growth of competitors) which allow oak regeneration to vigorously resprout following the subsequent burn. It mimics a disturbance pattern (i.e., partial overstory disturbance followed by fire) that has shaped the composition of eastern forests for millennia. The shelterwood-burn method is also economically attractive because the initial shelterwood cut yields an immediate income and the prescribed burn is low cost compared to alternative treatments.

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